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Rapeseed research and production in China

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ABSTRACT

Rapeseed (*Brassica napus* L.) is the largest oilseed crop in China and accounts for about 20% of world production. For the last 10 years, the production, planting area, and yield of rapeseed have been stable, with improvement of seed quality and especially seed oil content. China is among the leading countries in rapeseed genomic research internationally, having jointly with other countries accomplished the whole genome sequencing of rapeseed and its two parental species, *Brassica oleracea* and *Brassica rapa*. Progress on functional genomics including the identification of QTL governing important agronomic traits such as yield, seed oil content, fertility regulation, disease and insect resistance, abiotic stress, nutrition use efficiency, and pod shattering resistance has been achieved. As a consequence, molecular markers have been developed and used in breeding programs. During 2005–2014, 215 rapeseed varieties were registered nationally, including 210 winter- and 5 spring-type varieties. Mechanization across the whole process of rapeseed production was investigated and operating instructions for all relevant techniques were published. Modern techniques for rapeseed field management such as high-density planting, controlled-release fertilizer, and biocontrol of disease and pests combined with precision tools such as drones have been developed and are being adopted in China. With the application of advanced breeding and production technologies, in the near future, the oil yield and quality of rapeseed varieties will be greatly increased, and more varieties with desirable traits, especially early maturation, high yield, high resistance to biotic and abiotic stress, and suitability for mechanized harvesting will be developed. Application of modern technologies on the mechanized management of rapeseed will greatly increase grower profit.

1. Introduction

Rapeseed is the most important oil crop and the fourth largest crop in China after rice, maize, and wheat. As the world's largest rapeseed producer, China has ranked first in the world in total rapeseed production since 1980/1981, except for 2011/2012. There has been a steady trend of increase in total production, planting area, and yield of rapeseed in China for the last ten years (Fig. 1). Conventional rapeseed crop management is very expensive, labor-intensive, and inefficient owing to its low level of mechanization. A shortage of labor in rural areas and a lack of arable land available for commercial rapeseed cultivation have

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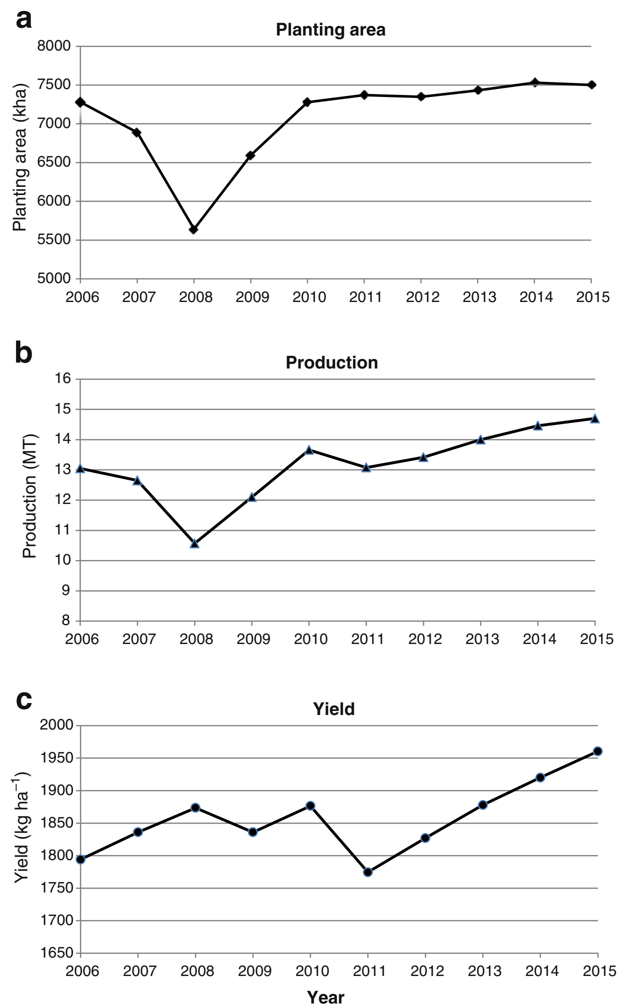

Fig. 1 – Rapeseed production in China over the last 10 years. (a) Planting area in kilohectares (kha); (b) production in metric tons (MT); (c) yield (kg ha^{-1}). Data from USDA (http://apps.fas.usda.gov/psdonline/).

put further pressure on farmers to adopt modern tools for mechanized farming. With the enhancement of research and extension of mechanization, the rapeseed industry has begun a transition from manual to mechanized farming. During the past three years, with the development of machines for seeding and harvesting, precision technologies for planting density adjustment, weed management, and controlled-release fertilizers, the planting area, total production, and yield per unit area of rapeseed has significantly improved. According to USDA data (http://apps.fas.usda.gov/psdonline/), rapeseed production in 2014/2015 in China reached 14.7 million tones.

In the last ten years, the quality of Chinese rapeseed has also been improved by advanced breeding and production technologies. Conventional rapeseed oil with high erucic acid has been changed to low-erucic acid oil with high nutritional value, and rapeseed meal with a low glucosinolate content has become a high-quality protein feed source instead of fertilizer. Data from the Center for Quality Supervision and Inspection of Oil and Products of the Chinese Ministry of Agriculture shows that rapeseed collected from areas covered by the National Rapeseed Modern Industry Technology System in 2015 had the highest average oil content (43.79%) and the lowest erucic acid content (4.00%) in history. The oil contents of the current varieties Zhongshuang 11 and Qinzayou 4 have exceeded 49% and 50%, respectively.

2. Rapeseed functional genomics and marker-assisted breeding

2.1. *Brassica* genomics and functional gene identification

Rapeseed genome sequencing research in China is recognized worldwide. In collaboration with international partners, China has completed the whole-genome sequencing of rapeseed and its parental species *Brassica oleracea* and *Brassica rapa*. Annotation was performed for 44,940 genes in *B. oleracea*, 41,174 in *B. rapa*, and more than 100,000 in *Brassica napus* [1–3]. Comparative genome analyses of the sequence assemblies have shown evolutionary patterns and genome duplications (72×) from the basal flowering plant species *Amborella* and thrice-duplicated genes from its parental species, *B. oleracea* and *B. rapa*. An international consortium involving Chinese researchers and the Illumina Company (www.illumina.com/) has developed a high-density 60K Infinium SNP array of rapeseed. This resource has been used worldwide, including the first report on QTL mapping for seed fiber content in rapeseed [4].

Functional genomics, as a supporting technology for molecular breeding, has become the focus of rapeseed research over the last ten years in China. Great progress has been made in China in the identification of functional genes for important traits such as yield, seed oil content, fertility regulation, disease and insect resistance, abiotic stress, nutrient-use efficiency, and pod shattering resistance (Table 1). In 2015, genes regulating both seed weight (*BnaA.ARF18.a*) and seed number per pod (*BnaC9.SMG7b*) were identified in China [5,6]. Rapeseed orthologs of *Arabidopsis* genes such as *SHB1* (*short hypocotyl under blue1*) and *HAIKU2* were shown to affect seed weight [7]. The transcription factors *LEC1* (*leafy cotyledon 1*) and *WRI1* (*wrinkled1*) were revealed to be involved in regulation of glycolysis and ultimately promote oil accumulation in seed [8,9]. Maternal organs including pod wall and seed coat were shown to affect seed oil content strongly in rapeseed [10,11]. Cytoplasmic effects were also shown to affect oil accumulation [12]. Two other genes, *GRF2* (*growth-regulating factor 2-like*, regulating photosynthesis and cell size) and *ORF188* (*open reading frame 188*, associated with cytoplasmic effects), were found to participate in a regulatory pathway involved in oil content [13,14]. Three genes for genic male sterility and restoration including *BnMs1* (*male sterility 1*), *BnMs2*, and *BnaC.Tic40* (*translocon at the inner membrane of chloroplasts with 40 kDa*) were cloned [15–17], deepening understanding of the mechanisms of male sterility. Genes associated with flower color (*BnaC3.ccd4*, *carotenoid cleavage dioxygenase 4*) [18], vitamin E biosynthesis (*hydroxyphenylpyruvate dioxygenase*, *HPPDase*) [19], and drought resistance (*sddt*) (unpublished data) have been identified recently. All these achievements of Chinese researchers have laid the foundation for rapeseed functional genomic research.

2.2. Molecular breeding research

Conventional molecular marker systems such as RFLP, SSR, AFLP, SRAP, and TRAP are being replaced with third-generation markers such as SNPs for molecular analysis. In China, several marker technologies such as SRAPs have been developed for rapeseed research [20]. With the advent of next-generation sequencing and the release of genome assemblies of *B. rapa*, *B. oleracea,* and *B. napus* and bioinformatics tools, it has been possible to develop genome-wide sequence-based markers via resequencing and genotyping-by-resequencing technologies. These markers are currently being used for genomic and functional genomics research in China. Using dozens of linkage and/or association population panels, thousands of QTL for agronomically important traits such as plant architecture, photosynthesis efficiency, flowering time, harvest index, yield, and its components, biotic and abiotic resistance, root architecture, nutrient use efficiency, fertility, adaptability, seed oil content and quality, and heterosis have been mapped in rapeseed and its close relatives such as *B. juncea* and *B. carinata* [4,21–46]. Of these, a few major genes or QTL accounting for a large proportion of genetic variation have been successfully cloned, as described above [5,6,15,17]. Markers linked to several major genes or QTL for traits of importance to rapeseed improvement programs have been successfully used in marker-assisted breeding [47]. However, it is still a great challenge to select complex quantitative traits such as yield using molecular markers. These complex traits are usually controlled by several quantitative trait loci having small effect and often interacting with environment. Several QTL (especially epistatic QTL) also show gene interactions that are beyond the detection power of most techniques and can be captured only by genomic selection (GS) [48]. Furthermore, many quantitatively inherited traits such as seed yield are complex and composed of many component traits [38], and affected by linkage drag, pleiotropy and physiological (such as by negative feedback) interactions among the components, making it more difficult to associate genotype accurately with phenotype.

With the gradual improvement of genetic transformation efficiency, a large amount of transgenic rapeseed has been produced worldwide. Several varieties carrying transgenic genes, especially for herbicide resistance, have been released for commercial production and are being adopted by farmers in many countries. In China, transgenics for resistance to herbicides, disease and insects, seed oil content, quality, and fertility regulation are being developed. However, only a few of the transgenic rapeseeds have proceeded beyond the experiment stage, and no genetically modified cultivar has been approved to date. A limiting factor for transgenic rapeseed breeding is the lack of high-value functional genes with both application prospects and independent intellectual property rights. The current situation calls for close attention to functional gene cloning and patent application. With continuous, stable funding of a series of research projects (such as the National High Technology Research and Development Program of China, the National Key Technology R&D Program of China, and National Rapeseed Modern Industry Technology System), a rapeseed molecular breeding platform (including a database of cultivars, molecular markers, phenotypes, QTL, etc.) has been developed in China. A new generation of genetic modification technology including TALEN (transcription activator-like effector nucleases), ZFN (zinc-finger nucleases), CRISPR/Cas (clustered regulatory interspaced short palindromic repeat/Cas-based RNA-guided DNA endonucleases) not requiring the introduction of foreign DNA has strong application prospects.

For future research, focus should be placed on the following three aspects: (i) cloning genes with high breeding and commercial value and patent them; (ii) developing high-throughput platforms for phenotyping, genotyping, and trait dissection; and (iii) integrating genome-wide selection and transgenic technologies for efficient breeding of rapeseed and improvement of grower profits.

3. Breeding of rapeseed varieties in China

From 2005 to 2014, 215 varieties of *B. napus* were nationally registered in China, including 210 winter-type and five spring-type varieties [49–51]. The average yield of the 210 winter-type varieties was 2689.8 kg ha^{-1}, with a range of 2151.4–3382.5 kg ha^{-1} (Table 2). Although the yield of varieties registered from 2009 to 2010 was relatively low, a yearly yield increase in varieties registered in 2005–2008 and 2009–2014 was observed, with the highest average in 2014 of 2998.3 kg ha^{-1}. Among the three yield components, a marked reduction of

Table 1 – Information about *Brassica napus* genes cloned in China.

Gene	Trait	Organization	Reference	Methodology
BnaA.ARF18.a	Seed weight	Oil Crops Research Institute, CAAS	[5]	Map-based cloning
BnaC9.SMG7b	Seed number per pod	Huazhong Agricultural university	[6]	Map-based cloning
SHB1/HAIKU2	Seed mass	Shandong Agricultural University (University of Minnesota at Twin Cities)	[7]	Homologous cloning
LEC1	Seed oil content	Institute of Genetics and Developmental Biology, CAS	[8]	Homologous cloning
WRI1	Seed oil content	Oil Crops Research Institute, CAAS	[9]	Homologous cloning
grf2	Photosynthesis and cell size	Oil Crops Research Institute, CAAS	[13]	Differential expression screening
orf188	Seed oil content	Oil Crops Research Institute, CAAS	[14]	Associated analysis
BnMs1/BnMs2	Male sterility and restoration	Huazhong Agricultural University	[15]	Homologous cloning
BnaC.Tic40	Male sterility and restoration	Huazhong Agricultural University	[16,17]	Map-based cloning
BnaC3.ccd4	Flower color	Huazhong Agricultural University	[18]	Map-based cloning
HPPDase	Vitamin E biosynthesis	Huazhong Agricultural University	[19]	Homologous cloning
sddt	Drought resistance	Oil Crops Research Institute, CAAS	Unpublished	Differential expression screening

Table 2 – Main characteristics of nationally released winter rapeseed varieties (2005–2014).

Year	No. of varieties	Yield (kg ha^{-1})	No. of siliques per plant	No. of seeds per silique	Thousand-seed weight (g)	Erucic acid (%)	Glucosinolate (μmol g^{-1} meal)	Oil content (%)	Growth duration (day)
2005	18	2490.99	387.45	20.08	3.46	0.62	22.22	40.83	224.52
2006	5	2545.07	414.10	20.36	3.56	0.25	22.61	41.70	227.70
2007	15	2699.52	401.42	20.72	3.64	0.23	22.87	42.51	224.49
2008	34	2782.15	419.58	20.65	3.83	0.19	21.39	43.84	229.31
2009	26	2590.03	390.14	20.43	3.74	0.17	22.82	43.39	224.66
2010	34	2601.77	396.39	20.26	3.74	0.19	24.59	43.11	227.31
2011	29	2662.75	343.75	20.24	3.91	0.25	22.12	43.89	224.46
2012	15	2785.31	283.92	21.75	3.49	0.28	22.27	43.41	225.01
2013	22	2861.25	280.52	21.13	3.85	0.19	21.83	44.88	224.37
2014	9	2998.33	279.20	20.78	3.61	0.09	23.55	42.30	221.89

effective siliques per plant has occurred since 2012, resulting from a change in plant density [52,53]. Seed per silique of registered varieties showed a yearly trend similar to that of yield. Thousand-seed weight of registered varieties varied slightly, with the highest value of 3.91 g in 2011. The average erucic acid and glucosinolate contents of the 210 winter-type varieties were 0.24% and 22.61% μmol g^{-1} meal, satisfying the Chinese standard of double-low rapeseed (erucic acid ≤ 3.0% and glucosinolate content ≤ 35.0 μmol g^{-1} meal) [53]. The average oil content of the varieties was 43.24%, ranging from 36.95% to 49.95%. The indices of *Sclerotinia* stem rot and viral diseases showed a tendency to decrease with breeding progress, indicating recent improvement in resistance in the registered varieties. The average growth duration of registered varieties was 225.74 days, ranging from 186.20 to 246.65 days (Table 2).

Statistical analysis of plant density data from national regional yield trials showed values varying from 225,000 to 300,000 plants ha^{-1} in 2005–2012 and increasing to 345,000–405,000 plants/ha^{-1} in 2013 and 2014. Increasing plant density resulted in marked alteration of yield components, especially the number of siliques per plant [54] (Table 3). The average yield of registered varieties grown at higher plant density (2013 and 2014) was 9.34% higher than that of varieties grown at lower density (2005 to 2012). The number of siliques per plant at higher plant density was significantly reduced by 26.63%, whereas the number of seeds per silique and thousand-seed weight increased by 2.58% and 1.69%, respectively. The registered varieties grown at higher plant density showed increased plant height and reduced branch number and growth duration compared with those grown at lower plant density.

4. Rapeseed production techniques

4.1. *Mechanization in rapeseed production*

Mechanization has continually increased in the rapeseed growing area in recent years. Rural professional organizations providing mechanized services for sowing, application of chemicals for weeds and disease, and harvesting are developing rapidly. At present, direct drilling is the main method of rapeseed planting and greatly reduces labor costs and improves soil structure. However, direct seeding needs longer land occupation time for rapeseed growth than seedling transplanting, leading to conflict on land use with rice planting in the subsequent season [55]. Given that seedling morphology (height, width, and root length) differs among varieties, characteristics of rapeseed seedlings provide useful guidance for the design and optimization of rapeseed transplanting machines [56]. In recent years, Yangzhou University and Nanjing Research Institute of Agricultural Mechanization, Ministry of Agriculture have jointly solved the technical problems associated with mechanical transplanting of rapeseed seedlings grown on special matrix forming blanket-like seedling assembling (blanket seedling) [57–59]. Experimental trials of mechanical transplanting of blanket seedlings have been successful in Jiangsu and Hubei provinces. Thus, mechanical transplanting technology will be rapidly extended, especially in areas with seasonal conflicts with rice planting in the subsequent season.

Yield loss by mechanical harvesting of rapeseed can occur not only in the process of threshing and cleaning but also in collision with machine in cutting process when harvesting is performed at an inappropriate time. Pod shattering-resistant varieties can reduce the loss from the cutting process, thus prolonging the appropriate time for harvesting. The loss rate for combine harvesting was less than 10% when the color of approximately 90% pods turned to yellow as a mature loquat coat [60]. The kinematics and dynamics of the cutting platform of a combine harvester have been analyzed [61]. Planting density is one of the most important factors affecting yield loss in rapeseed mechanical harvesting. The rate of seed loss during mechanical harvesting of rapeseed was smaller when plants were grown at high density and in a narrow row-planting pattern than in a low-density planting [62–64]. Regulating plant type with paclobutrazol is also a useful method of reducing mechanical harvest loss. Spraying of growth retardant with 150 mg L^{-1} paclobutrazol at a late stage of crop growth markedly reduced lodging and improved pod shattering resistance as well as seed yield [65].

4.2. *High-density planting for increased yield*

Although manual transplanting of strong seedlings at low planting density accounts for a large proportion of conventional rapeseed production, high-density planting is impossible in this model, owing to the heavy workload. With the current increase of mechanization in rapeseed production, manual transplanting has been much reduced because of the scarcity of labor. Direct

Table 3 – Comparison of main characteristics of registered varieties grown at different plant densities.

Year	Yield (kg ha^{-1})	No. of siliques per plant	No. of seeds per silique	Thousand-seed weight (g)	Plant height (cm)	Branch number	Growth duration (days)
2005–2012	2653.20	381.80	20.50	3.71	170.54	8.42	226.10
2013–2014	2901.05	280.14	21.03	3.78	175.77	7.19	223.65
Range (%)	9.34	−26.63	2.58	1.69	3.07	−14.61	−1.08

sowing makes the planting density uncontrollable under variable soil conditions. For this reason, high-density planting tends to be common owing to the impracticality of seedling thinning. Besides increasing plant leaf area index and light energy use efficiency, high-density planting can improve nitrogen use efficiency, promote the transformation of nitrogen to grain, and thus increase yield [66]. High-density planting can also improve the uniformity of the rapeseed population, making stems thinner, branches shorter, and maturation more synchronized, leading to marked reductions in seed loss during mechanical harvesting [67] and increased oil content [68]. Several studies have shown that rapeseed was more likely to achieve high yield in high-density plantings [63,66–68]. The optimum planting density is usually 30–60 × 10^4 plants ha^{-1}. The highest yield was achieved at a plant density of 45 × 10^4 plants ha^{-1} in combination with a narrow row spacing of 15 cm [63]. Rapeseed breeding for high planting density should focus on increasing silique density and number of siliques on the main inflorescence, as well as number of siliques per plant and seeds per pod [68,69].

4.3. *Application of controlled-release fertilizer*

With the development of rapeseed mechanization in China, optimum fertilizer rates under direct seeding and high-density planting conditions have been recommended [70]. Rapeseed production depends strongly on exogenous chemical fertilizer application, especially for nitrogen fertilizer, resulting in a yearly increase of nitrogen fertilizer application on a national scale recently [71]. Currently, the nitrogen use efficiency in China is lower than that in the developed countries. Excessive use of nitrogen fertilizer has exerted negative impacts on environments, human health, and the economy [72,73]. For this reason, an increase in fertilizer use efficiency is urgent. Application of a controlled-release fertilizer is one effective way to reduce chemical nitrogen fertilization without decreasing rapeseed yield. Compared to conventional application of nitrogen as base fertilizer alone, the application of controlled-release urea promoted the growth of rapeseed, resulting in a 7.1%–19.7% yield increase and a 12.2%–17.7% nutrient recovery efficiency increase [74]. In addition, several specialized fertilizers for rapeseed with multiple nutrients and long-lasting effect have been developed and have also improved rapeseed yield [75]. Straw residue incorporation is another practical way to reduce fertilizer use and improve farmland fertility worldwide [76]. Under the rice–rapeseed rotation system, straw residues contribute to rice production, increasing grain numbers in the rice panicle [77]. In the future, straw residue incorporation will become an important technique in the mechanized rapeseed production model. Further study on simultaneously increasing use efficiency and reducing the cost of controlled-release fertilizers is needed. In addition, accelerating the efficient decomposition of rapeseed straw residues deserves attention.

4.4. *Effective disease control and management*

Diseases and insects are major threats to rapeseed production worldwide. The major diseases in rapeseed production in China are stem rot and clubroot, caused by the phytopathogenic fungus *Sclerotinia sclerotiorum* and the protozoon *Plasmodiophora brassicae*, respectively. Managements were taken to monitor these major diseases and others such as downy mildew, white blister, and viral diseases. A key strategy is to identify plant resistance genes controlling various plant diseases. Some QTL for resistance to stem rot at the seedling and adult stages have been identified in the genome of *B. napus* [78–81]. Wei et al. [82] used the Brassica 60K SNP chip to analyze a diverse panel of 347 lines of rapeseed and identified 17 significant associations with resistance to stem rot on chromosomes A8 and C6.

Application of chemical fungicides plays an important role in controlling rapeseed stem rot at present. The emergence and application of drones has led to improvements in fungicide application and effectively controlled stem rot and other diseases of rapeseed. However, strains of *S. sclerotiorum* have developed resistance to fungicides under field conditions and shown high resistance to carbendazim and dimethachlon. For biocontrol of stem rot, composite microbial inoculants composed of *Trichoderma harzianum* Tri-1, *Aspergillus aculeatus* Asp-4, *Bacillus subtilis* Tu-100 and BY-2, and *Bacillus megaterium* A6 have been developed. A combination of spray and basal applications of the inoculants not only reduced sclerotial germination by 32.4% and disease index by 13.9%, but also reduced chemical pesticide application by 25% and increased rapeseed straw decomposition by 21.7% and rapeseed yield by 7.1% [83–85]. In addition, there are diverse mycoviruses in the fungus *S. sclerotiorum* and some of them can reduce the virulence of the fungal pathogen. Exploiting hypovirulent mycoviruses as biological agents may be another means of controlling this fungal disease in the future [86,87].

Clubroot, caused by the soilborne pathogen *P. brassicae*, is an emerging disease in China and is rapidly spreading in the major areas of rapeseed production. *P. brassicae* exists as various pathogenic populations showing different levels of virulence and divided into pathotypes 1–16 according to the Williams [88] system. Eight pathotypes have been identified so far, and pathotype 4 has been spreading throughout China and causing increasing damage to rapeseed and cruciferous crops [89]. Several loci involved in qualitative or quantitative clubroot resistance have been reported in *B. rapa* [90,91]. To date, genetic resources of clubroot resistance have been identified in Chinese *B. rapa* germplasm. Recently, isogenic lines of the rapeseed cultivar Huashuang 5 with introgressions from a resistant turnip showed robust resistance to pathotype 4 under both controlled and field environments [92]. This result suggests that clubroot is more reliably prevented through breeding than is stem rot in rapeseed.

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Aphid and diamondback moth are the major pests during the growth period of rapeseed and are controlled primarily by application of chemical pesticides. The seedling and bolting stages are the two pivotal periods for managing aphid populations. The insecticides imidacloprid and thiacloprid markedly reduce aphid damage. A major problem in the control of diamondback moth is the development of insecticide resistance. Avoiding the repeated application of the same insecticide is an efficient measure for the control of diamondback moth.

5. Conclusion and perspectives

5.1. *Large improvement in oil production of new rapeseed varieties*

To increase the oil content in Chinese rapeseed varieties, new breeding lines with superior agronomic traits have been developed by means of intergeneric hybridization, pyramiding of superior loci, microspore culture, and directional selection. These elite advanced breeding lines are being tested in national regional trials and a majority of them show oil content of above 45%. The oil contents of two varieties, Zhongshuang 11 and Qinzayou 4, have exceeded 49%. The average oil content of varieties developed in 2006–2010 reached 43.25%, increasing by 5.33% over that of 2001–2005. A major recent breakthrough in China is the development of a super-high oil rapeseed line, YN171, with an oil content of 64.8%. With continuous efforts in genetic improvement, after 10 years, the average oil content of rapeseed varieties may increase by more than 4%.

5.2. *Mechanized production will become the common mode*

The development of machines for precise rapeseed seeding and harvest, integrated with high-density planting, herbicide weeding, controlled-release fertilizer, and straw decomposition will enable the adoption of mechanization. This achievement will improve production efficiency, reduce production costs, and increase the gross margin of rapeseed growers in China. In 2014, the rapeseed mechanized harvesting area reached 41%, with an annual growth of more than 8% in Hubei province. With the continuous improvement of agricultural equipment, China could achieve the mechanization of rapeseed production in five years.

5.3. *Development of new varieties with early maturity, high yield, high resistance, and high production efficiency will be facilitated in response to urgent need*

The development of early-maturing (in 3–5 days) conventional and hybrid varieties having high (up to 67%) seed oil content and suitable for mechanization will make rapeseed a more profitable crop in China. In addition, the development of new rapeseed varieties with short growth period for double or triple cropping systems (for example, middle-season rice with rapeseed, or early-season rice, ratoon rice, and rapeseed production in southern China) and with high nutrient use efficiency, improved biotic and abiotic resistance (to *S. sclerotiorum* and clubroot), tolerance to drought, waterlogging and frost, and improved oil quality (high oleic acid content) will also expand the rapeseed industry in China.

5.4. *Expansion of the rapeseed industry*

Rapeseed could also be used for other markets beyond its use as a source of edible oil and livestock feed meal. The most important new function of rapeseed may be as an effective rotation and fallow crop for soil protection. In the future, rapeseed can be used for rotation with rice and maize in a two-season cropping system region in the Yangtze River valley; as oilseed, forage, and green manure for rotation and fallow in southern China; for rotation with wheat and maize once every 2–3 years in the regions of the Yellow and Huai River; for rotation with wheat and barley in northern China; and for rotation and fallow with other crops in cold and arid regions. Given that rapeseed has high biomass production and high protein content in its vegetative parts, it is also a favorable choice for forage production and green manure. As an ornamental plant species, rapeseed contributes greatly to the beautiful landscape of yellow flowers in the springtime fields along the Yangtze River Valley as well as the unforgettable summer scenery around Qinghai Lake in northwest China.

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